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Published under Authority

of

HON. J. ANGUS MACLEAN, M.P.,
Minister of Fisheries

Observations on the Spawning of Lake Trout, *Salvelinus Namaycush*, and the Post-spawning Movement of Adult Trout in Lake Simcoe

by

H. R. McCrimmon

Ontario Agricultural College, Guelph, Ont.

Introduction

The material presented in this paper comprises a summary of observations made on spawning populations of lake trout in Lake Simcoe between 1951 and 1957. The majority of the data was collected at the extensive Glenrest Beach shoals at the north end of the lake where submarine trap-nets were set each autumn by the Fish and Wildlife Division of the Ontario Department of Lands and Forests for the collection of lake trout eggs as a part of Ontario's fish culture programme. Records of the post-spawning movements of parent fish from the Glenrest Beach shoals were obtained by the recovery of tagged fish by anglers.

Description of Lake Simcoe

Lake Simcoe, the fourth largest inland lake of Ontario, has an area of 280 square miles but a relatively short and generally exposed shoreline of only 144 miles, including that of the few islands. The average depth has been calculated at 56 feet with some six per cent of the lake over 90 feet deep (Rawson, 1930). The main body of the lake is oval in shape with a long deep bay, Kempfenfeldt Bay, on the west and a shallow bay, Cook's Bay, on the south. The shoreline of the lake is about 55 per cent stony, 35 per cent sandy, and the remaining 10 per cent capable of supporting vegetation in rich muddy bays. On account of the wide variety of habitat conditions present, Lake Simcoe is ideally suited for the production of both warm water and cold water fishes which enables an active sport fishery at all seasons of the year (McCrimmon, 1956). Habitat conditions are very favourable for the reproduction, growth, and harvest of lake trout.

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Spawning Grounds

Lake Simcoe provides extensive shoal areas for the spawning of lake trout. The trout spawn on shoals located along the shores of the mainland and few islands, also on several submerged mid-lake shoals. These shoals are covered characteristically by wave-washed gravel, rubble, and stones, and are quite free of silt. Some 50 per cent of the shoreline of the lake is suitable for trout spawning and at some locations the stony beaches extend off-shore in excess of 500 feet before reaching water depths of 20 feet. Several submerged shoals are over a mile in length. Spawning generally takes place in less than 20 feet of water, occurring frequently at depths of two to ten feet.

Pre-Spawning Movement of Adult Trout

The lake trout appeared at the spawning shoals of Lake Simcoe early in October, the actual dates varying between October 4 and October 9 in the years from 1951 to 1956. The autumn migration of the trout from the depths of the lake was, of course, coincident with dropping surface water temperatures and the fall turnover. During the years of study, surface water temperatures were between 50° and 57°F. at the time of arrival of the lake trout. The arrival of the trout on the spawning shoals each year followed one or more days of strong winds, averaging over 10 m.p.h. in velocity for a 24-hour period and with gusts in excess of 15 m.p.h. These statistics support the observations of local fishermen that strong winds are necessary before the trout come to the shoals.

A summary of weather conditions on the day previous to the evening when trout were first observed on the shoals is given in Table I.

Table I

Summary of Weather Conditions on First Date of Appearance of Lake Trout on the Shoals

Year	Surface Water Temp. Deg. F.	Air Temp. Deg. F.		Wind Conditions			Hours of Sunlight	Synopsis
		Min.	Max.		M.P.H. Av.	M.P.H. Max. (1 hr.)		
1951	52	44	50	Strong	20	27SW	0.0	Overcast, drizzle rain-showers
1952	50	45	55	Mod.	11	20SW	2.5	Overcast, with clear intervals
1953	54	54	75	Mod.	15	19N	2.9	Generally overcast, rain-showers
1954	54	32	50	Mod.	11	23NW	3.2	Overcast by 10 a.m. rain
1955	57	57	61	Strong	19	25E	0.0	Overcast and rain
1956	57	41	55	Mod.	12	26NW	8.5	Cloudy, clearing by 9 a.m.

Activity of Trout on Spawning Shoals

The time during which the adult lake trout are concentrated on the spawning shoals can be divided conveniently into two periods: *the pre-spawning interval* when the trout frequent the shoals but are not yet ready to spawn, and the *spawning period* when the eggs are laid and fertilized.

Chronological data on the movements of trout to the shoals and the subsequent spawning periods are given in Table II.

Table II

Observations on the Autumn Movement and Spawning of the Lake Trout

Year	Night of Arrival of Trout at Shoals	Night of First Known Spawning	Peak Spawning Period	Night of Last Known Spawning	Duration of Spawning Period
1951	Oct. 8	Oct. 17	Oct. 21-25	Oct. 29	12 days
1952	Oct. 5	Oct. 15	Oct. 17-19	Oct. 24	9 days
1953	Oct. 6	Oct. 16	Oct. 19-21	Oct. 25	9 days
1954	Oct. 6	Oct. 21	Oct. 25-28	Nov. 1	9 days
1955	Oct. 5	Oct. 24	Oct. 27-30	Nov. 2	10 days
1956	Oct. 4	Oct. 14	Oct. 22-27	Oct. 29	16 days

(1) *Pre-Spawning Interval*

The adult lake trout frequented the spawning shoals of the lake for a variable length of time each year before actual spawning began. This period between the advent to the spawning shoals and the initiation of spawning each year varied from a minimum of nine days in 1951 to a maximum of 19 days in 1955. A summary of weather conditions which occurred during the pre-spawning interval is tabulated in Table III.

Table III

Summary of Weather Conditions between the Arrival of Trout on Shoals and Initiation of Spawning Part (*a*)

Year	Duration of Interval	Av. Water Temp. Deg. F. at Surface	Water Temp. Total Degrees Below 60°F.	Average Mean Air Temperature Deg. F.
1951	9 days	53 (50-60)	61	51 (38-72) normal
1952	10 days	52 (48-56)	85	48 (32-66) below normal
1953	10 days	55 (52-61)	50	50 (30-69) below normal
1954	15 days	56 (51-58)	75	54 (28-74) above normal
1955	19 days	55 (50-66)	85	62 (30-75) above normal
1954	10 days	54 (54-57)	43	50 (31-72) below normal

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Part (b) Table III.—*Continued*

Year	Total Hours of Sunlight	Wind Conditions		Synopsis
		Av. Daily (m.p.h.)	% of Days with Max. Vel. Greater Than 10 m.p.h.	
1951	60.6	7.4	13	Generally clear, no rain
1952	61.5	8.1	0	Generally clear, rain only last 2 days
1953	64.8	8.6	10	Generally clear, rain only on Oct. 11th
1954	64.8	12.7	50	50% clear, 50% overcast, rain on 6 days in mid-period
1955	60.8	9.9	62	40% clear, balance rain
1956	61.6	10.7	60	Generally clear, rain only on Oct. 7th and 9th

A comparison of a number of measurable weather conditions (*see* Tables III and IV) occurring during the pre-spawning interval which may have influenced the length of the interval suggested a correlation only with the total hours of sunlight accumulated after the arrival of the trout on the shoals. In each year approximately 60-65 hours of sunlight had occurred at the time of first spawning. While it is recognized that spawning began each year with water temperatures between 52° and 57°F., temperatures in this range did not precipitate spawning. In five of the six years between 1951 and 1956, water temperatures had dropped to 55°F. or less by October 9 but spawning did not begin until some days later when some 60 hours of sunlight had been accumulated. No correlation was apparent between the duration of the pre-spawning interval and other limnological, meteorological, or astronomical factors studied. The significance of the apparent correlation between accumulated sunlight following the arrival of the trout on the shoals and the initiation of spawning, which may be only a coincidence, would seem worthy of further investigation.

(2) *The Spawning Period*

A considerable variation has been observed in the date of first spawning during the years of study, a maximum difference of 10 days being noted between the start of spawning in 1955 and 1956.

Table IV

Summary of Weather Conditions on the First Day of Spawning.

Year	Night of First Known Spawning October	Surface Water Temperature	Wind Conditions During Day	Duration of Sunlight Hours	Phase of Moon
1951	17th	53°F	light (6.3NE)	6.4	past full
1952	15th	52°F	light (8.2SW)	1.0	none
1953	16th	56°F	light (5.4NW)	9.0	past 1 Q.
1954	21st	52°F	light (7.5NW)	9.7	third Q.
1955	24th	52°F	strong (19SW)	0.5	past 1 Q.
1956	14th	54°F	light (5.9SW)	7.4	past I Q.

Reference to Table IV reveals no uniformity in weather conditions at the initiation of the spawning period other than a water temperature of 52° to 56°F. Winds were generally light in contrast to the strong winds that marked the arrival of the trout on the spawning beds although heavy winds occurred during the first day of spawning in 1955. Sunlight varied from a maximum in excess of nine hours to overcast skies. Rain occurred on two occasions. As noted above in the text, it is possible that the extent of accumulated sunlight during the pre-spawning interval may directly or indirectly influence the time of spawning.

The spawning period extended over a period varying from nine to 16 days between 1951 and 1956. A summary of average weather conditions which prevailed during each of the spawning periods is given in Table V.

Table V

Summary of Weather Conditions During the Lake Trout Spawning Period

Year	Duration in Days	Water Temperature		Air Temp. Deg. F.	Hours of Sunlight
		Average Deg. F.	Day Degrees Below 60°F.		
1951	12	59	70	54	28
1952	9	49	58	44	64
1953	9	55	30	57	47
1954	9	52	56	48	57
1955	10	49	97	48	29
1956	16	52	119	55	84

Observations on the spawning activity of the lake trout revealed that maximum activity was usually reached within four days after spawning began and continued at a high level for the next three to five days, by which time the majority of trout were spawned out. The spawning activity then decreased abruptly and there was an exodus of trout from the spawning areas within the next three or four days.

An analysis of environmental factors which might be expected to affect spawning activity has shown no definite correlation of any factor other than wind. Local fishermen state that heavy onshore winds and rough water generally result in a short spawning season whereas calm weather allows spawning over a more prolonged period. Observations made on the spawning runs at Glenrest beach indicated that strong onshore winds hastened the peak in spawning activity once the fish had begun to spawn and this shortened the overall spawning period. A comparison of the more-or-less normal spawning periods of the years between 1951 and 1955 with the extended spawning period of 1956 shows a relationship between onshore winds and spawning activity.

In the years from 1951 to 1955, onshore winds followed closely after the initiation of spawning and peak spawning activity occurred within two to four days. In contrast, during the extended spawning season of 1956 there were no onshore winds until over a week after spawning was first noted and spawning activity remained at a low level. Spawning activity increased rapidly in 1956, eight days after spawning had begun with the arrival of moderate southerly onshore winds which developed into strong winds for the remainder of the peak spawning period.

Species of Fish Frequenting Lake Trout Spawning Shoals

The captures of fish made by two 15-foot submarine trap-nets on the Glenrest beach spawning shoals during October for the collection of lake trout eggs are recorded in Table VI. The kinds and numbers of fish frequenting the shoals are apparent in this Table. Between 1951 and 1956, some 3,547,000 fertilized lake trout eggs were collected for culture.

Table VI

October Capture of Fish by Two Submarine Trap-nets Set at the Glenrest Beach Spawning Shoal between 1951 and 1956.

Duration of Netting		Number of Fish Captured												
Year	Operation	Lake Trout	Whitefish	Pickerel	Maskinonge	Catfish Family	Rainbow	Pike	Smallm. and largem. Bass	Carp	Suckers	Burbot	Cisco	Perch
1951	Oct. 3 to Oct. 30	1341	2004	435	0	232	2	23	63	8	193	20	0	1
1952	Oct. 7 to Oct. 25	1218	2987	126	0	952	0	40	10	11	522	86	0	0
1953	Oct. 5 to Oct. 23	835	425	1368	0	735	0	33	50	11	228	3	4	0
1954	Oct. 5 to Oct. 30	1089	4130	352	1	1551	1	16	23	11	710	16	2	0
1955	Oct. 3 to Nov. 2	1135	7694	238	0	674	0	26	206	2	465	68	0	0
1956	Oct. 5 to Oct. 30	445	10588	2535	0	269	0	22	65	4	531	48	0	17
	Total.....	6063	27828	5054	1	4413	3	160	417	47	2649	241	6	18

Post-Spawning Movement of Adult Lake Trout

A total of 500 lake trout were tagged from captures of 3,059 trout made by submarine trap nets set on the Glenrest Beach spawning shoals at the north end of the lake during the early part of October in the years 1953, 1954, and 1955.

The trout were tagged with coloured plastic tags attached at the base of the dorsal fin by nylon thread. Most records of the recovery of tagged fish were provided voluntarily by anglers.

The purpose of the study was to follow the movements and distribution of adult lake trout after leaving the spawning beds in order to determine firstly, if the spawning population was a local one restricted to a segment of the lake and, secondly, if there was any evidence of a homing behaviour among the trout. A summary of the recovery of tagged trout is given in Table VII. The locations of recoveries are shown in Figure 1.

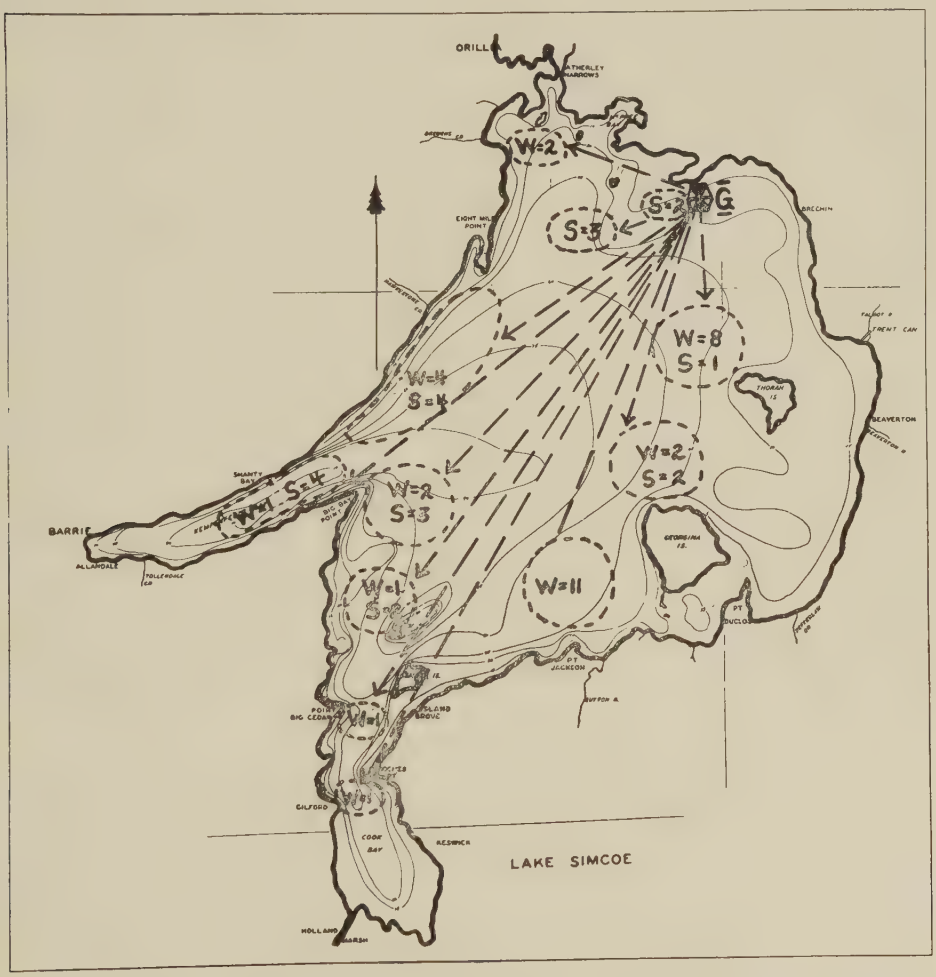

Figure 1.—Recoveries of tagged lake trout in Lake Simcoe, G = Location of tagging, S = Summer recoveries, W = Winter recoveries.

Table VII

Summary of Recovery Records for Adult Lake Trout Tagged on Glenrest Beach Spawning Grounds.

Year of Tagging	Time of Recovery	Number of Trout Recovered	Maximum Lineal Distance Travelled	Percentage Recovery
1953	Winter 1953-54	8	8.3 mi.	
	Summer 1954	7	10.1	
(150 fish	Winter 1954-55	2	12.8	
tagged)	Summer 1955	3	9.0	
	Winter 1955-56	7	11.2	
	Summer 1956	2	8.5	
	Winter 1956-57	1	5.3	
	Total	30		20.0
1954	Winter 1954-55	2	8.2	
	Summer 1955	4	10.5	
(200 fish	Winter 1955-56	1	8.2	
tagged)	Summer 1956	0	—	
	Winter 1956-57	5	9.8	
	Total	12		6.0
1955	Winter 1955-56	6	8.0	
	Summer 1956	3	11.3	
(150 fish	Winter 1956-57	2	3.8	
tagged)	Total	11		7.3
	Grand Total	53	12.8	10.6

A study of the recapture records shows (1) that 10.6 per cent of the 500 lake trout tagged between 1953 and 1955 had been recovered by March 1, 1957. Additional recoveries are anticipated. A comparatively high return of 20.0 per cent resulted from the 1953 tagging, a low figure of 6.0 per cent from the 1954 tagging, and a return to date of 7.3 per cent for the 1955 tagging project. Over 63 per cent of the recoveries were made by winter anglers, 37 per cent by summer anglers, and the remainder by trap nets set at Glenrest Beach.

(2) That those trout which spawned at the Glenrest Beach shoals became widely distributed in Lake Simcoe at other seasons of the year and occupied all those deep basins of the lake where trout normally congregate. The greatest distance recorded between the point of release and that of recapture was nearly 13 lineal miles. As the lake trout are limited to several deep-water areas during the heat of summer and recaptures of tagged trout occurred at each of these locations, one may conclude that there was a mixing of trout from all spawning areas of the lake during the summer stagnation period at least.

(3) That there was no evidence of a homing behaviour to the spawning beds among the lake trout, only two of the tagged fish having re-appeared in the trap nets set on the Glenrest Beach shoals although nearly 2,700 lake trout were handled during the 1954, 1955 and 1956 spawning seasons. The homing behaviour recorded by several authors (Martin 1957) may be influenced in Lake Simcoe by the unusually great expanse of suitable spawning beds and the similar character of the various shoals.

Summary

Observations were made on the spawning and movement of adult lake trout between 1951 and 1957 in Lake Simcoe, a lake ideally suited for the production of this species and its harvest by anglers.

The adult lake trout approached the spawning shoals during early October in each of the study years when surface water temperatures had dropped to between 52°F. and 57°F. Strong onshore winds occurred immediately before the arrival of the trout and would appear necessary to bring the trout to the shoals.

The lake trout frequented the shoals for a pre-spawning interval between nine and 19 days before actual spawning began. A relationship observed between the duration of this period and the extent of accumulated sunlight would seem worthy of further study.

The spawning period varied from nine to 16 days. Maximum spawning activity was reached within four days (except in 1956), continued at a high level for from three to five days, then decreased rapidly with an exodus of trout from the shoals within the next three or four days. Strong onshore winds appeared to hasten the peak in spawning activity and thus shorten the overall spawning period.

Tagged lake trout from a specific spawning shoal became widely distributed in the lake at other seasons of the year, the recovery of over 10 per cent of these trout representing a mixing of trout from all spawning areas of the lake at least during the summer stagnation period. There was no evidence of a homing behaviour among the adult lake trout in Lake Simcoe.

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The Survival of Yearling Lake Trout Planted in South Bay, Lake Huron*

by

F. E. J. Fry and J. C. Budd

Department of Zoology,
University of Toronto,

and

Research Division,
Ontario Department of Lands and Forests.

Introduction

Shortly after the Fisheries Laboratory had been established on South Bay, an inlet into Manitoulin Island which lies in northern Lake Huron, it became evident that there had been no substantial lake trout spawning there after 1944 or 1945. The reason for this lack of adult lake trout was not immediately apparent but subsequently it has appeared certain that at least the final reduction and the continued absence of adult trout have been due to predation by the sea lamprey, *Petromyzon marinus*. Because of the lack of native spawning stock, a programme of experimental planting of marked yearling lake trout was begun in 1949 and plantings were made each year thereafter, except for 1950, ending in 1955. In addition, a spring planting of unmarked fry was made in 1955. The details of these plantings are given in Table I.

The main purpose of these plantings was simply to determine as accurately as possible the degree to which such fish would survive to catchable size and to compare their growth rate and behaviour with data already available from native South Bay lake trout. However, with the continued predations of the sea lamprey, the plantings have also enabled us to extend our study of the effect of the lamprey on the lake trout beyond the period when the natural population of this species had disappeared. It is hoped now, in particular, to gather data which may be of value in predicting the success of any future efforts to rehabilitate the lake trout in the upper lakes when the current sea lamprey control programme shows promise of success.

Planting Procedure

The stocks planted were from Lake Superior except for one year when some Lake Simcoe fish were included. They were reared to the end of the second summer in various Provincial Hatcheries. (*See* Table I.) A few days before planting the fish were moved to the Sandfield rearing station about ten miles from the South Bay laboratory.

*Presented at the 10th meeting of the Canadian Committee for Freshwater Fisheries Research, Ottawa, January 4, 1957.

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It is felt that the recovery period thus allowed, after a long trip either by truck or by air, is a valuable precaution against planting them in an overfatigued state with lessened chance for survival (Black 1956). They were then moved in small loads to the laboratory and placed in three-foot square hatchery tanks aboard the boat from which they were to be planted. The fish were planted over broken rock along the shore of the upper basin of the bay in 10 to 20 feet of water. The areas chosen for planting were the same areas where native lake trout were known to have spawned. The fish were distributed evenly along the shoreline by tossing them overboard from the slowly moving boat by means of a scap net. Only from three to five fish per netful were handled, thus allowing the planter to keep an accurate count. Distribution was at the rate of approximately 2,000 fish per mile of shoreline. The plantings were delayed until surface temperatures were 55°F. (12.8°C.) or lower. The plant of unmarked advanced fry made in May of 1955 was air-dropped in the manner commonly used in stocking inaccessible lakes.

Some weeks prior to planting, all yearlings were marked by removing the adipose fin with a razor blade. The same mark was used on every plant, reliance being placed on scale reading to separate the groups when captured.

Approximately 1,400 planted fish, so recognized by the absence of their adipose fins, have been recovered to date. Along with these, 185 other lake trout have been taken for which the lack of an adipose has not been recorded or for which its presence has been specifically noted. The fish thus recognized as unmarked have been consistently about 10 per cent of the total sample from each year class for which plantings were made, except for the hatch of 1951. Samples from that year class have contained 14 per cent. The fall of 1950 was the only one during the period when adult trout were noted on the spawning beds. It has been estimated (Fry 1953) that egg deposition in that fall was of the order of 50,000 to 120,000 eggs. The increased incidence of unmarked fish from the 1951 hatch, although not statistically significant, is possibly, therefore, to be ascribed to this small spawning. It would appear then that it can safely be presumed that the majority of the unmarked lake trout that have been taken in South Bay in late years are planted fish that were improperly clipped or for which the clips were not recognized when they were handled after recapture. A summary of the numbers of lake trout taken in South Bay classified by marking and year class is given in Table II.

Growth of Planted Fish

The age length relation of the various samples of the planted fish are shown in Figure I in comparison with the curve obtained for the native fish taken from Fry (1953). The ages were estimated from impressions on cellulose acetate read on various projectors or in some cases with a binocular microscope. The first year's growth showed the complex pattern recently described by Cable (1956). Scales from samples of the fish planted and of certain fish which had been tagged before planting and later recaptured, were available to enable the position of the first annulus to be placed. Little difficulty was experienced in reading the scales and internal evidence indicates that the readings are in general reliable. For instance no fish of the 1949 year class were planted and only four marked fish of the adjacent year classes were incorrectly

assigned to that group. In addition, as Figure I shows, the growth curve of a given year class tended to remain consistent in its course in comparison with other year

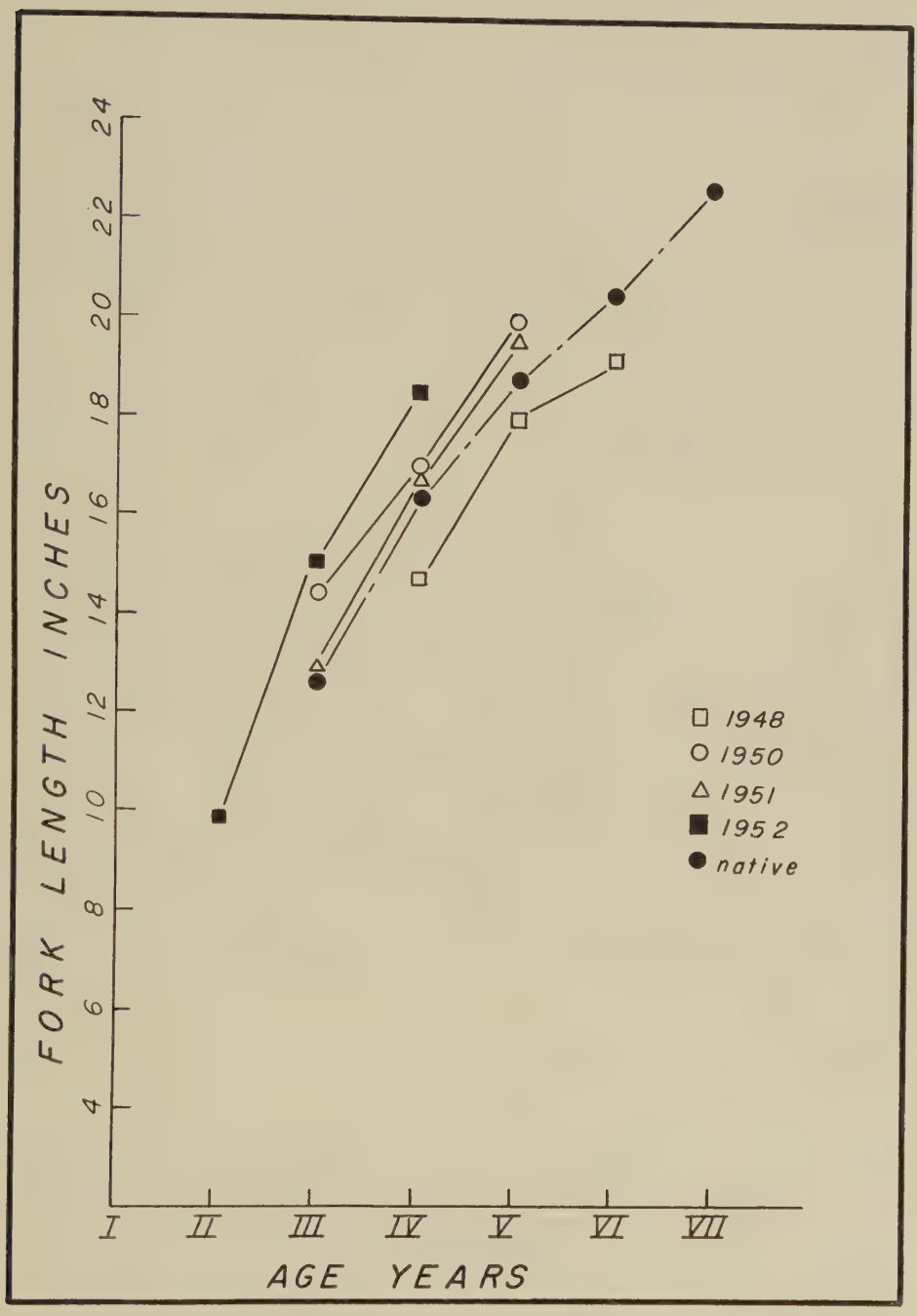

Figure I.—Growth of South Bay lake trout showing a comparison between the various year classes of hatchery stocked fish and the native stock.

classes. Note for example the curve for the 1948 year class. It can be seen that the growth of the planted fish has been in general the same as that which was displayed by the native stock. The 1948 year class (planted in 1949), which consisted of fish known to have been small when planted, although the sample taken for measurement was lost, showed the smallest size at a given age throughout its history.

In addition to the growth curves in Figure I, which are assessments based on scale reading, a direct comparison, based on marking and recovery data of the growth of planted fish for the year 1956, can be made with native fish for 1949. Twenty-seven of the fish released with tags in June of 1956 were recaptured in September and October. These fish had a mean length of 18.6 inches when released at a mean date of June 16. They were recaptured at a mean date of September 13 and had gained a mean increment in length of 1.3 inches. From Fry's (1953) Figure 2 it may be estimated that over the same period in 1949, native lake trout of similar size gained 1.1 inches.

The samples of 1956 also gave an estimate of the intraseasonal growth of the age II individuals. Two samples of approximately 20 fish each were taken, one in June and the other in September. The mean length of the June sample was 9.5 inches, that of the September sample 11.5 inches.

Survival

In 1956 it was possible to make direct estimates of the sizes of the population of two of the year classes of planted lake trout, those of 1951 and 1952. These estimates were of the Petersen type and were made by releasing tagged trout taken in pound nets in the spring and recapturing a fraction in gill nets in late summer. The number of tagged fish released was 98 estimated to be age IV and 52 of age V. Of these, 15 age IV fish were recaptured with 276 untagged fish of the same age. The number of tagged fish of age V retaken was 10 together with 93 untagged ones. These data give Petersen estimates, in round numbers, of 2,000 age IV lake trout and 500 age V present at the time of tagging. These two estimates yield widely different percentage survivals from the two plants. Only two per cent of the 23,100 yearlings of the 1951 year class are thus estimated to have survived to age V, whereas 45 per cent of the 1952 year class of 4,500 planted are estimated to have survived to age IV. It has not been possible to make any further direct estimates of the number of survivors from other plants by the mark recapture method. However, some estimates are given below based on catch per unit effort.

Pound net catches

Five pound nets have been fished in essentially the same locations in South Bay since fishing started in 1947. In certain of the earlier years additional pound nets were set, but for comparative catch-effort studies only the five basic nets have been considered. The catches of the five nets in question for the month of June are listed in Table III. June has been taken as the best month for comparison since the nets almost invariably can be expected to take trout throughout that month. In some years it was not possible to get all nets set and fishing much before the first of June so comparisons of May fishing would include very irregular sections of that month. Also in

some years the trout retreat to deep water early in July, therefore weather might be expected to greatly influence comparisons made for that month. In general, pound net fishing for lake trout extends from mid-May to mid-July with June being the most productive period. Even in June it is possible that water temperature in some years has an influence on the pound net catch of trout; therefore the catch per unit effort of these nets cannot be considered a precise estimate of the relative size of the lake trout population from year to year.

The possibility of using the catch per unit effort to give rough estimates of the survival of the planted lake trout in South Bay rests on the series of population estimates made for the native lake trout population which still existed there until 1951. Population estimates of both the Schnabel and the Petersen types were made for the lake trout in the years 1948 through 1952 (Fry 1953). Petersen estimates were made again in 1956 as is discussed above. These various estimates, together with the catch per unit effort calculated for the same years, form the basis of the estimates of population size made for the other three years in which pound net catches were of any significance. Thus from the first five rows of Table III it may be estimated that, over the ages represented, a catch of one lake trout per lift represents a population of 775 lake trout present in South Bay. The data shown show no trend in the catch per unit effort with age so that it is not worth while to calculate the means for the individual ages. The population estimates given in the lower four rows of Table III are derived from the mean relation of C.U.E. and catch given above.

In Table IV the population estimates for the planted fish given in Table III are related to the year classes. There is undoubtedly a great deal of uncertainty to be attached to these estimates. For example the estimate for the size of the 1951 year class at age IV is obviously wrong since approximately 200 individuals of this year class were taken in the sampling at ages IV and V after this estimate was made (*see* Table II). The season of 1955 in which the low population estimate was obtained was distinguished by being the warmest on record during the course of our observations. For that reason the pound net fishing for trout was terminated early, as the fish withdrew to deeper water, and the estimates based on the whole of the June fishery, would be expected to be low. In any event, while the percentage error may be gross, the values appear to indicate the order of magnitude of the various year classes in the fishery.

Percentage survivals to age V based on the estimates are shown in the last column of Table IV. A notable feature of the estimates is that the numbers surviving have borne no direct relationship to the numbers planted. Indeed, as far as the data go, the relation has been inverse which seems to indicate that at present the conditions in South Bay are such that no more than 1,500 or so lake trout can survive to age V regardless of the size of the plant. It will be of interest to see whether such continues to be the case as the histories of the plants are followed further. This appears to be a rather surprising circumstance since earlier conditions permitted age V populations several times this number. The only obvious change in the environment which might be expected to affect the lake trout at sizes beyond those at which they were planted is the sea lamprey.

Another notable feature of Table IV is that fish of the 1948 year class did not survive to age VII, the age at which most females reach maturity, nor did the 1950 year class survive to age VI. These losses can both certainly be attributed to the depredations of the sea lamprey. This points out rather clearly why it is possible for the lamprey to completely eliminate a lake trout population by effectively halting all reproduction.

Lamprey Scarring

The scarring data are summarized in Table V which continues the type of summary given for the years 1947 through 1951 in Fry (1953) except that the size classes above 19 inches have been further condensed. The table is based on records of all fish handled during the period either killed or released. Fresh and healed scars have been combined.

Lamprey scarring on fish 19 inches and over has continued at the level attained in 1950 and was much increased in four of the later years. The apparent drop from the 1950 value in scarring on fish under 19 inches is due largely to the capture of many more fish under 16 inches in the net sampling during the years reported here. The 1950 sample was taken by angling and very few fish were captured that were under 18 inches. Thus many more fish of the lengths that are immune to scarring are included in the samples since 1950. In general the evidence from the scarring data indicates that the first year of substantial lamprey attack on the lake trout in South Bay was 1949 and that severe attacks began in 1950. The data for 1951 and 1952 are weak. Scarring probably continued at the 1950 level until the end of 1954. The severity of lamprey attack has further increased in the two last years of the records, 1955 and 1956.

The argument that the lack of healed scars on small lake trout is perhaps only an indication that virtually every attack at this size is fatal and that the mortality from this cause may be actually greater among small fish than among large ones, is not supported by the evidence gathered in South Bay. The South Bay data suggest rather that a wave of mortality (not due to lamprey) may come among the small fish early after planting and that the lake trout are then relatively immune to further losses until they approach twenty inches in length. In 1955, 89 fish from six to nine inches in length were tagged at the time of planting. During the 1956 fishing operations, nine of these tagged fish were recovered, ranging in size from 11 to 14 inches. The recovery of these tagged fish does not indicate any substantial mortality from lamprey attack among lake trout up to 14 inches long. It is rare that a lamprey scar is observed on fish of these lengths.

If the size composition of a year class of lake trout is followed through, year by year, in detail in South Bay, it seems that the loss by lamprey attack sharply increases as the fish approach a length of 20 inches, regardless of age. It is this circumstance apparently that has prevented the lake trout from living to be much older than age V in late years in South Bay. The single year class that reached age VI in substantial numbers, the 1948 year class, had apparently been retarded in the first and second year and did not attain the critical size as early as did the other year classes.

Conclusions

1. To date the plantings have shown that it promises to be quite feasible to rehabilitate a lake trout population in the Great Lakes by the planting of yearling stock. In the absence of lampreys two to 50 per cent of such planted fish could have been expected to have reached maturity in South Bay. It is possible, but not yet proven, that the maximum efficiency could be obtained with relatively small introductions, for the data suggest that about the same absolute number of lake trout have survived regardless of the number planted.

2. The stocks introduced into South Bay have behaved in growth and distribution in essentially the same manner as did the native stock.

3. When sea lamprey are present in substantial numbers, planted lake trout can still survive in numbers for several years and apparently become highly susceptible to lamprey attack only after reaching a certain critical size which in South Bay is approximately 20 inches fork length.

4. It is improbable that any planted lake trout will survive to spawning in South Bay while the sea lamprey maintains its present population desntity there.

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Table I

Summary of Lake Trout Planting in South Bay, Lake Huron.

Year Class	Number Planted	Date Planted	Average Length[1]	Origin of Eggs	Rearing Station
1948	(100's) 71	Oct. 1949	no record (small)	Lake Superior	North Bay
1949	0	.....	.....	.....	.....
1950	101	Oct. 1951	5.3 (68)	Lake Superior	Chatsworth
1951	231	Nov. 1952	3.7 (176)	Lake Superior	Sault Ste. Marie
1952	45	Oct. 1953	4.1 (41)	Lake Simcoe and Lake Superior	Chatsworth
1953	184	May 1954	3.6 (92)	Lake Superior	Chatsworth
1954	157	Nov. 1955	6.2 (185)	Lake Superior	Chatsworth
1955	510 (est.) advanced fry, air dropped	May 1955	1.5 (no actual measurements)	Lake Superior	Sault Ste. Marie

[1] Based on sample measured, number of fish in sample shown in parentheses.

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Table II

Numbers of Lake Trout Taken in South Bay in the Years 1952 to 1956.
(The numbers in brackets are unmarked fish.)

Year Class	Number Planted	II	III	IV	V	VI	VII	Total	Per cent Unmarked
	(100's)								
1947	0	.....	.....	.....	0(4)	1(0)	1(1)	7	.....
1948	71	.....	.....	73(16)	90(14)	79(2)	.....	274	11
1949	0	.....	2(0)	0(4)	2(2)	.....	.....	10	.....
1950	101	2(0)	12(3)	85(8)	20(2)	9(1)	.....	142	10
1951	231	0(1)	24(6)	25(4)	149(22)	.....	.....	231	14
1952	45	17(5)	63(14)	386(40)	.....	.....	.....	525	11
1953	184	30(5)	193(18)	.....	.....	.....	.....	246	9
1954	157	140(13)	.....	.....	.....	.....	.....	153	9
Total...	.....	.....	.....	.....	.....	.....	.....	1588	.....

Table III

June Catches of Lake Trout in South Bay Pound Nets.

Year	June Lifts	Catch	Catch/life or C.U.E.	C.U.E. by Age Gronps				[1]Population Estimates			
				IV	V	VI	VII	IV	V	VI	VII
1948	44	1383	31.4	27.3	4.0	0.1	.....	16,700	2,500	300	.....
1949	132	1559	11.8	2.7	9.1	.....	.....	3,200	10,800	.....	.....
1950	69	477	6.9	.....	1.7	5.0	0.2	.....	1,000	3,000	160
1951	84	50	0.6	.....	.....	0.1	0.5	.....	.....	125	475
1956	50	160	3.2	2.1	1.1	.....	.....	2,000	500	.....	.....
								Based on C.U.E. and above estimates			
1952	Insufficient data										
1953	39	56	1.4	.....	1.4	.....	.....	.....	1,400	.....	.....
1954	30	40	1.3	0.4	.....	0.9	.....	310	.....	700	.....
1955	51	17	0.3	0.1	0.2	.....	.....	80	160	.....	.....

[1] Estimates based on mark recapture data prior to 1956 from (Fry 1953).

Table IV

Population Estimates in Relation to Age for Various Year Classes of Planted Fish.

Year Class	Age				Per Cent Survival to Age V
	IV	V	VI	VII	
1948		1 100	700	0	15
1950	310	160	0	.....	2
1951	80	500	.....	.....	2
1952	2,000	.....	.....	.....	"40"

Table V

Percentages of Lake Trout from South Bay Examined Bearing Lamprey Marks, a dash indicates a negative finding on a sample of less than 10 fish.

Year	Fork Length, Inches		
	Under 19	19-21	22 and Over
1949	1	4	11
1950	14	20	25
1951	—	54	37
1952	4	50	19
1953	9	18	—
1954	6	17	—
1955	14	56	71 (7 fish)
1956	12	47	85 (13 fish)

59417-6—4½

Notes on the Food of the Young of Three Species of Pacific Salmon in the Sea

by

Murvel E. Annan

University of Washington

During July, 1950, very considerable numbers of young pink, chum and spring Pacific salmon were taken in beach seining operations in the San Juan Island area, carried out as part of the work in a course in Fish Biology given at the Oceanographic Laboratories of the University of Washington at Friday Harbor, Wash. Cursory examination of some stomach contents of these fish revealed the presence of dipterous larvae and pupae in addition to crustaceans, and so from July 10 to 31, 206 specimens were preserved for more detailed examination.

In the final analyses of the data, no differences were found in the nature of the foods among the three species of salmon or in relation to the size of the fish. The data were therefore not segregated.

The species were represented as follows: pink salmon, *Oncorhynchus gorbuscha* 103; chum salmon, *O. keta* 54; and spring salmon, *O. tshawytscha* 49; total 206. The total lengths of the fish ranged from 4.0 to 9.5 cm., with a mean length of 6.5 cm.

The food materials of the total number of fish were estimated to be: Copepoda 50 per cent; Diptera (larvae and pupae) 26 per cent; miscellaneous items including small crustacea (copepods, isopods, amphipods) and unidentifiable material 24 per cent.

Since the presence of Diptera was surprising, special attention was given to the identification and occurrence of this food item.

Reference to publications by Saunders (1928) and Johannsen (1936) readily led to the identification of the insect as *Camptocladius pacificus* Saunders in the family Chironomidae. However, systematists at the present time appear to prefer to consider *Camptocladius* as a sub-genus of the genus *Spanistoma* (from correspondence with the U.S. National Museum). On this basis the name is *Spanistoma pacifica* (Saunders).

Examination of larvae and pupae was made after clearing specimens in xylol and mounting in paramount. Drawings are presented in Figure 1.

The data on occurrence are given in Tables I and II. When the Diptera were more abundant than other food items, they were recorded as predominant. Fewer Diptera were eaten as the season progressed. Either they became fewer or other food forms became more plentiful.

The writer is indebted to Dr. W. A. Clemens for suggesting the study.

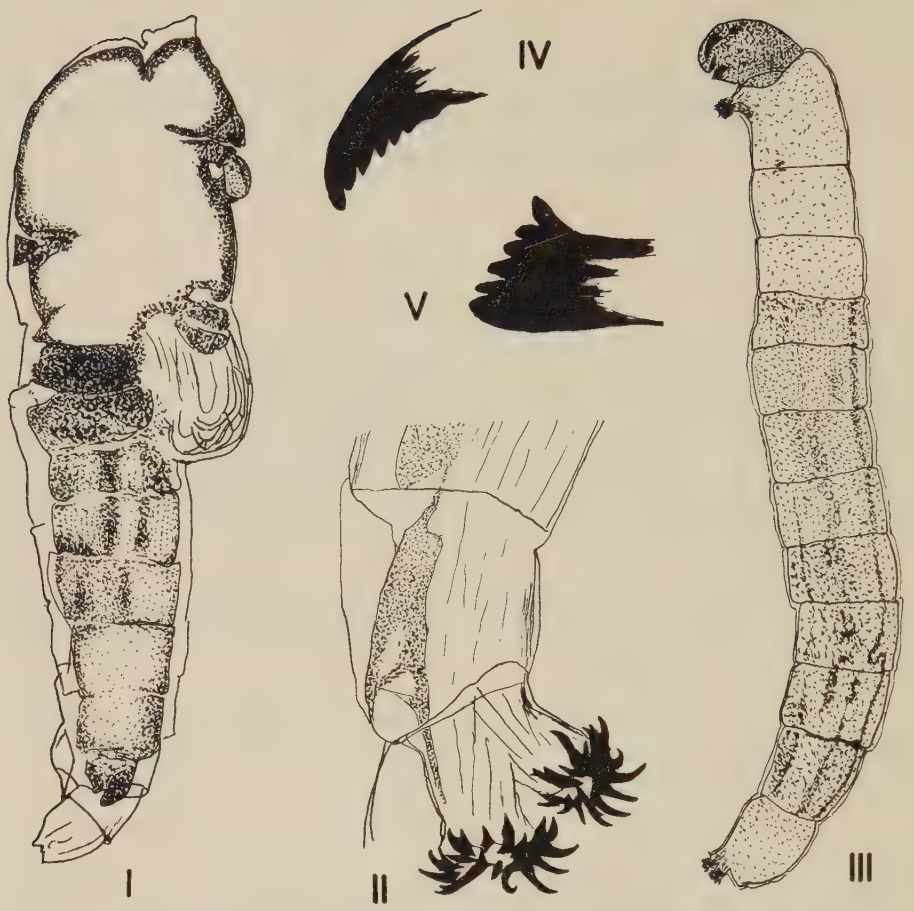

Figure 1.—Spanistoma pacificus (Saunders). I Pupa. II Anal pseudopod showing hooks. III Larva. IV Mandible. V Labium. Drawings made with the aid of a camera lucida.

Table I

Diptera, *Spanistoma pacifica*, in the Stomachs of Young Salmon.

Date	Number of Salmon	Number Having Diptera Predominant	Per Cent	Number Having No Diptera	Per Cent
10 July	7	4	57	0	0
10 July	32	18	56	3	9
10 July	20	14	70	2	10
10 July	17	4	24	3	18
10 July	8	2	25	1	13
17 July	18	0	0	10	56
17 July	35	11	31	6	17
17 July	8	1	13	4	50
24 July	6	0	0	4	67
24 July	11	0	0	7	64
24 July	1	0	0	1	100
31 July	28	0	0	24	86
31 July	15	0	0	15	100
	206	54	26	80	39

Table II

Occurrence of Diptera, *Spanistoma pacifica*, in the Stomachs of Young Salmon by Weeks.

Week of	Number of Salmon	Number Having Diptera Predominant	Per Cent	Number Having No Diptera	Per Cent
10 July	84	42	50	9	11
17 July	61	12	20	20	33
24 July	18	0	0	12	67
31 July	43	0	0	39	91
	206	54	26	80	39

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A Direct-Current Electrofishing Apparatus Using Separate Excitation

by

A. R. Murray

Fisheries Research Board of Canada,
Biological Station, St. John's, Newfoundland

In order to determine the standing crops of Atlantic salmon, brook trout, and eels in the Little Codroy River, Newfoundland, a direct-current electrofishing apparatus using separate excitation has recently been devised. Separate excitation is a simple and practical method for getting excellent output voltage control. It is also a safer and more economical means of producing power for electrofishing. The purpose of this paper is primarily to describe the unit and report briefly on some results of its use.

The electrofishing apparatus consisting of engine, generators, control panel, cable and reel, positive fishing electrode, and negative ground electrode, is shown in Figure 1A. The source of power is a 6.5 h.p. Briggs and Stratton air-cooled, gasoline engine. An engine of this size was selected in order to take advantage of its relatively low r.p.m. characteristics (2,400 r.p.m.). The generators are belt driven (Figure 1B), with the exciter generator turning at 1,440 r.p.m., and the main generator at 1,250 r.p.m.

The wiring diagram for the electrofishing apparatus is shown in Figure 2. The main generator (Figure 1C) is a rebuilt, separately excited, direct-current unit mounted in an "Imperial Electric" frame. The armature is capable of producing a maximum unloaded potential of 675 volts at 3 amperes continuous service, or 4 amperes intermittent service. The resistance of the armature is 4 ohms. The field is wound for separate 12-volt excitation with an external field rheostat mounted in the control panel for output control. The resistance of the field is 36 ohms. Interpole windings are used to improve voltage regulation under varying load conditions.

The exciter generator (Figure 1D) is a Lucas 12-volt, shunt-wound, direct-current generator. There are three reasons for using separate excitation. First, excellent voltage control can be obtained using separate excitation (along with interpole windings) because field troubles from variable voltage and load are minimized. Separate excitation means that the main generator has a low voltage separately excited field (i.e., 12 volts, as compared with 675 volts if the generator were self-excited). This minimizes the danger of insulation breakdown and flashover in the damp conditions existing beside rivers. Second, safety is a feature of separate excitation because 12 volts are used to control 675 volts. There are actually two safety factors involved: (*a*) the 12 volts separate excitation, and (*b*) the relay which is mounted in the control panel. The 12-volt generator is the source of power for the relay. The switch in the handle of the positive electrode (Figure 2) controls the relay, and the relay, in turn, controls the

field of the main generator. Thus there is just enough low voltage current flowing through the electrode switch to operate the relay. Third, because the resistors, relay, and switches are in the 12-volt circuit they are low priced and easily obtainable.

The control panel (Figure 1E) consisting of field rheostat, voltmeter, ammeter, 12-volt relay, and main switch, is mounted in a standard steel junction box. The

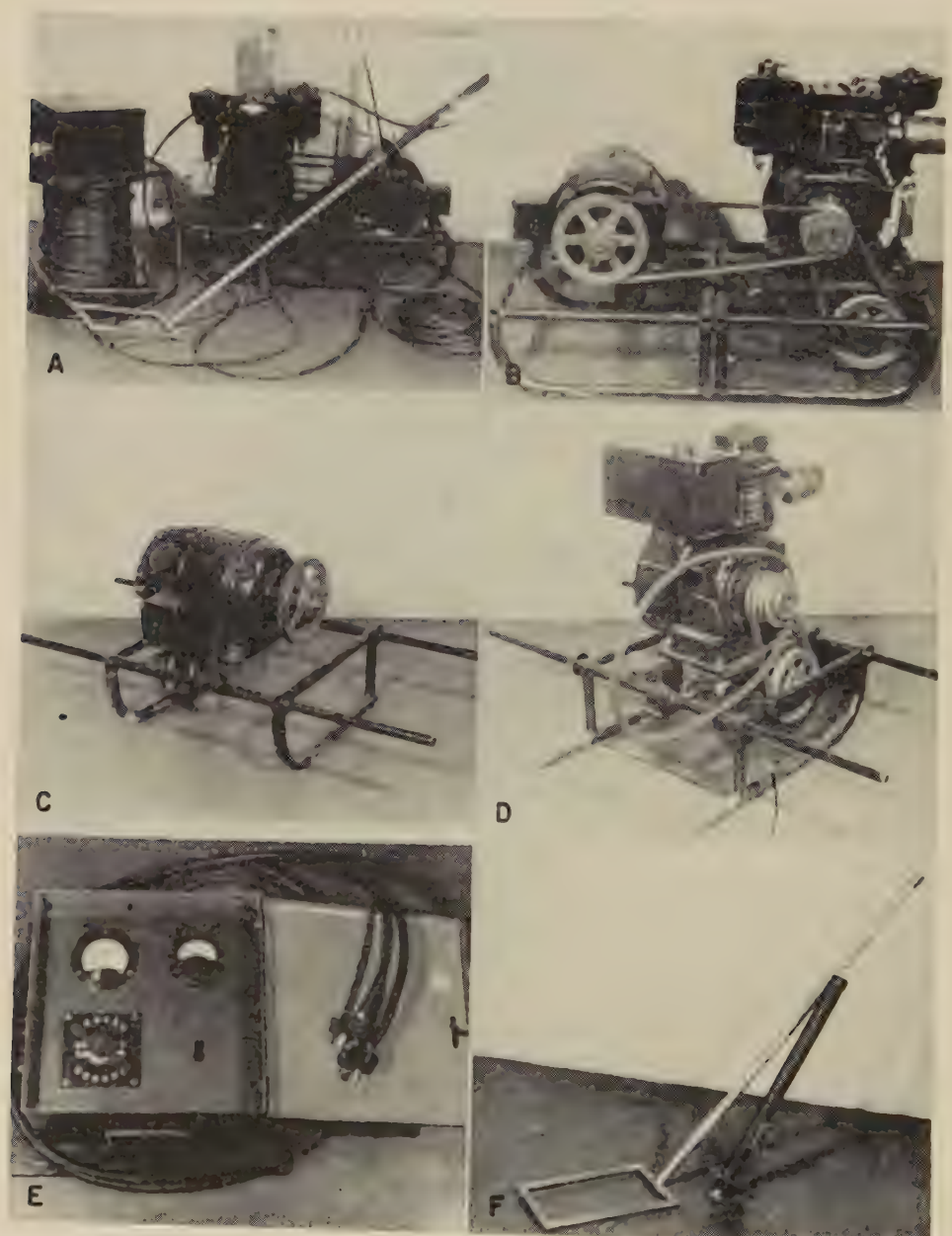

Figure 1.—Direct-current electrofishing apparatus.

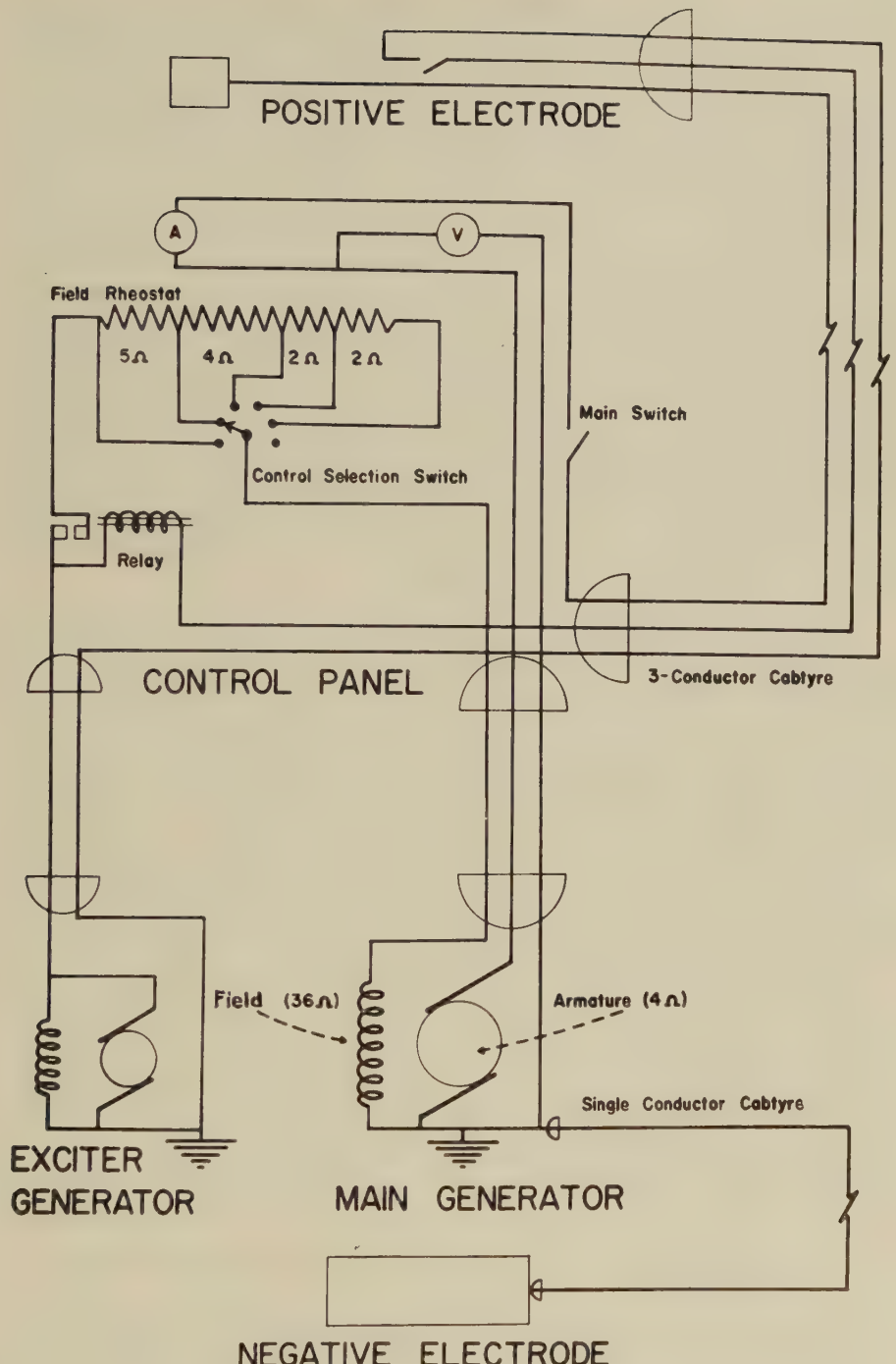

Figure 2.—Schematic wiring diagram of direct-current electrofishing apparatus.

control switch on the 13-ohm field rheostat allows the selection of any one of 5 output voltages (unloaded values): 200, 300, 400, 520, and 675. The variable output voltage is a useful feature for it allows the selection of the voltage best suited to the conductivity of the water, as well as the size and species of fish being collected. The control panel is separate from the engine and generators, the circuits being completed by means of two short cables from the control panel plugged into polarized receptacles on each generator.

The engine and generators are bolted to a light weight tubular steel (bicycle-type) frame made in two sections, one carrying the engine and exciter generator, and the other the main generator. The weight of the engine and exciter section is 168 pounds, and the weight of the main generator section is 144 pounds. The two sections are carried separately (Figures 1C and 1D), but are bolted together when the unit is in operation (Figures 1A and 1B). The main generator can be moved back and forth on its frame to allow for belt adjustment. As suggested by Smith and Elson (1950), the engine and generators are mounted on two frames for convenience in handling because of their weight. However, an overall improvement in portability has not resulted because of their bulk and also because of the weight of some of the accessory gear (such as the barrier nets). Hence it is possible to use this equipment only in the areas of the river which are accessible by vehicle.

The cable reel (Figure 1A) is a metal flanged drum which carries 300 feet of 3-conductor, number 14, cabtyre cable. One end of the cable is plugged into a polarized receptacle on the control panel, and the other end into a polarized receptacle on the handle of the positive fishing electrode. In practice, the reel is mounted on a horizontal axle, which is supported by a stand made of steel pipe, and the approximate amount of cable required is pulled from the reel and stretched along the stream bank. The man operating the fishing electrode drags the cable behind him. The negative pole of the main generator is grounded by connecting it through 100 feet of single-conductor, number 14, cabtyre to a 3- by 10-foot piece of copper hardware cloth which is set on the stream bottom and covered with rock or gravel. The single-conductor cable is also carried on the reel. The total weight of the reel and both cables is 114 pounds.

The positive fishing electrode (Figure 1F) consists of a straight piece of $\frac{5}{8}$ inch copper tubing, on the distal end of which is a rectangular piece of $\frac{1}{2}$ inch copper tubing, size 8 by 11 inches. The proximal end of the electrode is attached to a tubular insulated handle by means of a brass coupling. There is a sliding contact switch on the handle which indirectly controls the main generator through the relay, hence the high potential will not be produced unless both the electrode switch and relay are closed. All members of the electrofishing crew wear electrician's rubber gloves and rubber chest waders.

A Jeep and 2 wheel, $\frac{1}{2}$-ton trailer are used to transport the crew, apparatus, and accessory equipment.

The unit has been used under a wide variety of conditions on the Little Codroy River, and has proven highly satisfactory. It has, for example, been used in both winter and summer in water ranging from 2.8°C. to 19.2°C. It has been used in various parts of the drainage basin in water the resistivity of which has varied from 19,800

to 42,200 ohms per centimeter cube ($\Omega/cm.^3$). The positive fishing electrode has been fished up to 400 feet from the negative ground electrode with no apparent decrease in efficiency.

The total numbers of fish captured at the various sampling stations are shown in Table I. Because this work is in its preliminary stages, a more complete analysis is not given. The data are included only to indicate that the apparatus has been successfully used to catch Atlantic salmon parr, brook trout, and eels under a variety of conditions. The method of blocking off the sample areas with barrier nets, and the fishing procedure used at each station were much the same as that described by Godfrey (1956).

Observations on the behaviour of Atlantic salmon parr, brook trout, and eels in the direct-current field parallel those of Godfrey. As reported by Saunders and Smith (1954), it was found that collection of fish was easiest when the generator voltage was adjusted so that the fish could be held at the positive fishing electrode in a condition of partial paralysis. The potential was around 300-375 volts. In general, voltages around 300 were found to be more satisfactory in warm water, whereas voltages around 375 were more satisfactory in cold water. This complements the findings of Smith and Elson.

Table I

Numbers of fish taken at each of the sampling areas, Little Codroy River, 1956.

Station Number	Atlantic Salmon Parr		Brook Trout	Eels
	Under-yearlings	Yearlings and Older		
2	38	35	0	31
3	26	57	1	46
5	31	47	1	27
6	63	30	23	53
8	237	22	10	5
9	1	3	0	28
16	92	78	19	59
16a	110	74	13	5
17	0	39	4	32
18	56	47	15	18
19	29	89	2	66

In connection with voltage adjustment, it was observed that the lower the resistivity of the water, the lower the voltage produced, and the greater the current drawn, at any one setting of the control selection switch on the field rheostat. For example, when the control selection switch was set so that the main generator was

producing 650-675 volts (no load), under load in water of 19,800 Ω/cm.^{3} resistivity it was producing 330 volts at 1.7 amperes, and in water of 42,200 Ω/cm.^{3} resistivity it was producing 600 volts at 0.9 amperes. The effect of water temperature and water resistivity on voltage adjustment were also observed in a general way. At any given resistivity, the higher the water temperature, the lower the voltage produced, and the higher the current drawn. For example, with the control selection switch set as above, the main generator produced 500 volts at 1.2 amperes in water of 40,200 Ω/cm.^{3} and 15.3°C., whereas it produced 600 volts at 0.9 amperes in water of 42,200 Ω/cm.^{3} and 4.4.°C.

Some immediate mortality was observed in two instances when fishing in rapid water over rubble bottom when dislodged and shocked parr drifted downstream into the lower barrier net and were held by the pressure of the water and by the accumulation of debris on the net. This occurred early in the season when the apparatus and its attendant techniques were new to the crew. As the season progressed and the crew became more proficient, there was no further immediate mortality.

Shortly after the unit was completed in January 1956, it was tested in the Salmonier River, St. Mary's Bay, Newfoundland. Approximately 160 Atlantic salmon and brown trout parr were collected. These fish were brought back to the Biological Station and held for observation in wooden troughs and glass aquaria for a period of one month. There were no mortalities during this period. Accordingly, delayed mortality has been assumed to be not significant, and it has further been assumed that fish which recovered immediately from the effects of the electroshock were uninjured. Similar conclusions have been drawn by Smith and Elson.

Acknowledgements

Assistance in the design of the apparatus by Mr. W. Brown, of the Department of Transport, St. Andrews, Newfoundland, Mr. R. C. Hawksford, of the Vocational Institute, St. John's, and Mr. M. A. Foley, of the Fisheries Research Board of Canada, Technological Unit, St. John's, is gratefully acknowledged. The apparatus was built by Canadian Machinery and Industry Construction Limited, St. John's. This paper is published with the permission of the Fisheries Research Board of Canada.

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Back-pack Fish Shocker

by

A. A. Blair

Fisheries Research Board of Canada, Biological Station, St. John's, Newfoundland.

The value of small, portable, electrical fish shockers is fast becoming apparent to fishery workers. The immediate need for such a unit in Newfoundland was for collecting live salmon parr for laboratory experiments on tagging. The intention was to assemble a unit similar to one described by Haskell *et al.* (1954). Difficulty was experienced in obtaining the specified parts locally, but this was overcome by obtaining a packaged D.C. unit, the Vibrapack, with a similar circuit from P. R. Mallory & Co. Inc., Indianapolis, Indiana.

Description

The complete shocker is shown in Figure 1. It consists of a 6-volt motorcycle battery, the Vibrapack, and a voltmeter housed in a fairly water-tight box and two paddle-type electrodes. The outside dimensions of the box are 15 inches wide, 15 inches high, and 8½ inches deep. A pack-sack frame is attached to the box so that the outfit can be carried comfortably on the back. The electrodes, which are made of ½ inch copper tubing, are 4½ feet long, the round end being 7 inches in diameter. The grid in the round end is formed of heavy copper wire. A switch in the low voltage D.C. circuit for starting and stopping the unit is conveniently located on the handle of the right or positive electrode. A switch for use as a main switch or in emergencies is situated on top of the case. It has a pull cord which is readily accessible to the operator or the second man of the team. The unit SHOULD NEVER be used by one man alone.

The total weight of the outfit is 44 pounds, so it can be carried fairly easily by one man. The cost in St. John's, Newfoundland, was $120.00. (It should be less in most other cities in Canada.) The following is a list of parts and materials used:—

Parts

Battery.....6-volt motorcycle battery, Lucas PUZ 7E-9

Vibrapack.....Mallory VP-555H

Voltmeter.....0-500 V.D.C., 1,000 ohms per volt, Triplett

Main fuse.....30 amp.

Vibrapack fuses.....10 amp. 3 AG

Switch No. 1.....Open knife, SPDT, mounted on outside of case

Switch No. 2.....Slide switch, SPST, mounted on positive electrode handle

Relay.....Automobile horn relay, Sorensen HR-2

Discharge resistor R-4.....400 K safety resistor

Materials

Electrodes.....$\frac{1}{2}$ inch copper tubing

Electrode handle insulation.....$\frac{5}{8}$ inch automobile heater hose

Electrode connections.....For positive electrode, three conductor No. 12 cab tyre

For negative electrode, single conductor No. 12 cab tyre

Battery connections.....No. 6 insulated flexible cable

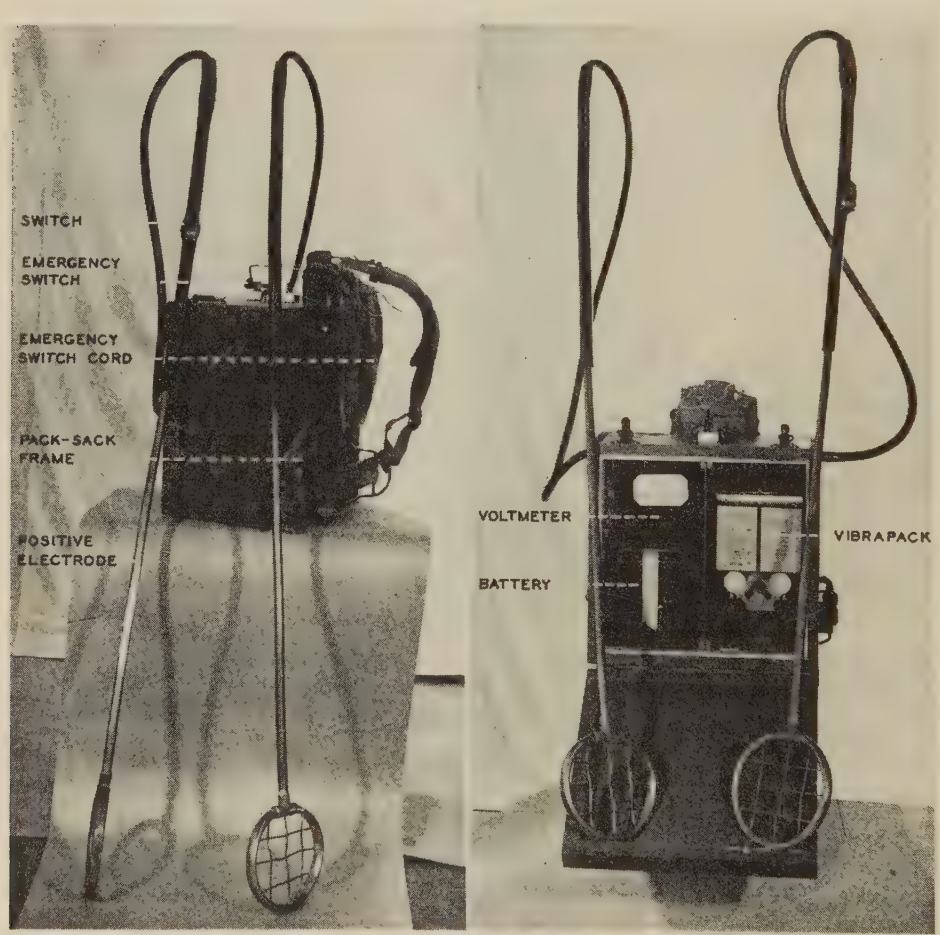

Figure 1.—On the left a view of the shocker ready for use, and on the right a view of the interior.

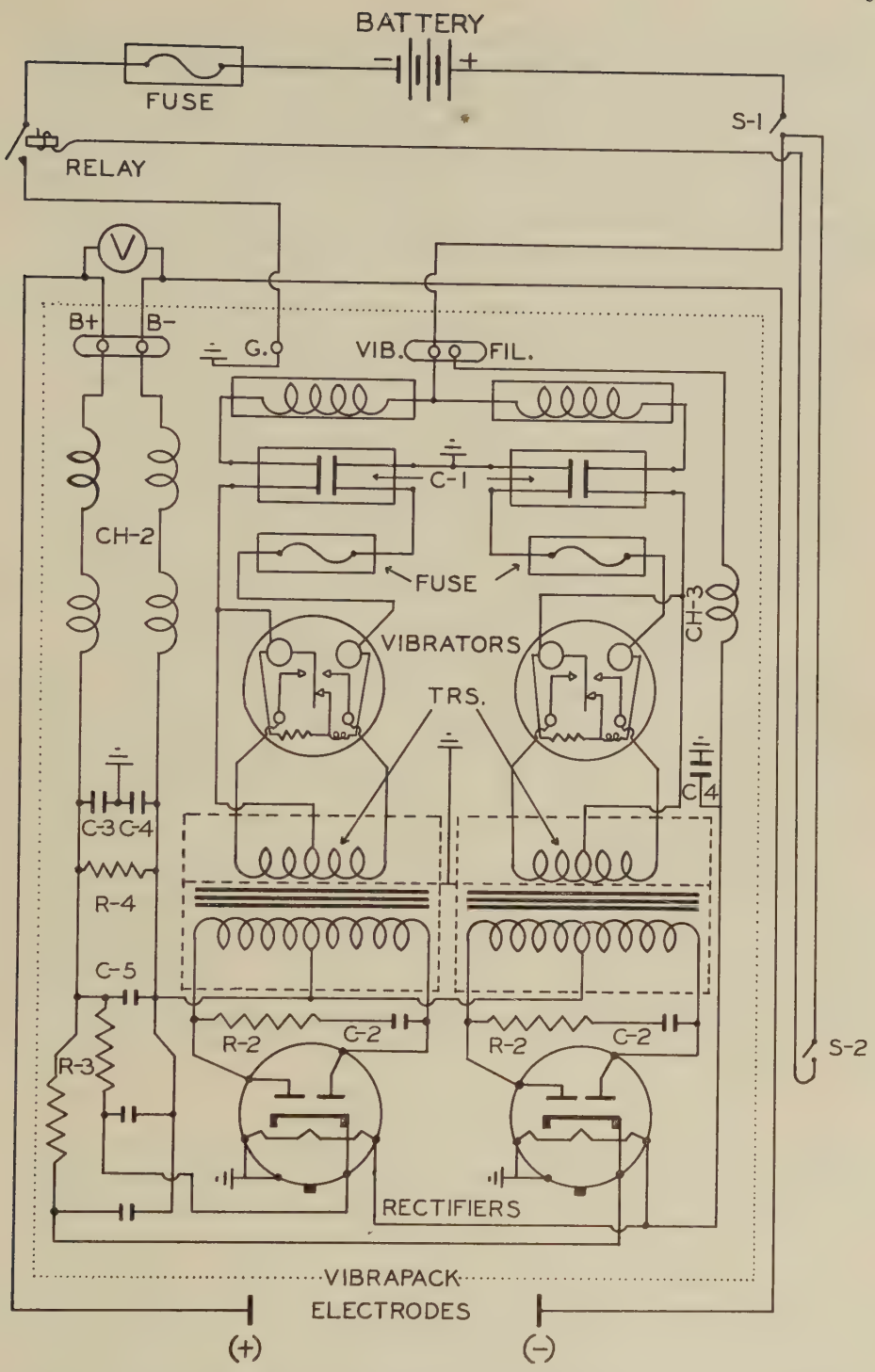

Figure 2.—Schematic wiring diagram. Symbols: B—, battery negative; B+, battery positive; C-1, C-2, C-3, C-4, condensers; CH-2, CH-3, chokes; FIL., filament; G, ground; R-2, R-3, R-4, resistors; S-1, S-2, switches; TRS., transformers; VIB., Vibrapack; and (V), voltmeter.

The Vibrapack or main power unit is factory built. Types are available for nominal input of 6, 12, and 32 volts, nominal output ranging from 125 to 400 volts, and maximum output of 60, 100, 150, and 200 milliamperes. The one selected for operation in Newfoundland streams has a nominal input of 6 volts, a nominal output of 300 volts, and a maximum output of 200 milliamperes. The wiring diagram of the Vibrapack unit is shown within dotted lines in the schematic wiring diagram of the shocker (Fig. 2). For ease in assembly and to give good connections all wires have soldered terminals. The Vibrapack is supplied with OZ4A rectifier tubes which according to the manufacturer's description require a minimum current load of 140 milliamperes to start the unit. However, in this particular installation it was found that the unit would start with a load as low as 90 milliamperes.

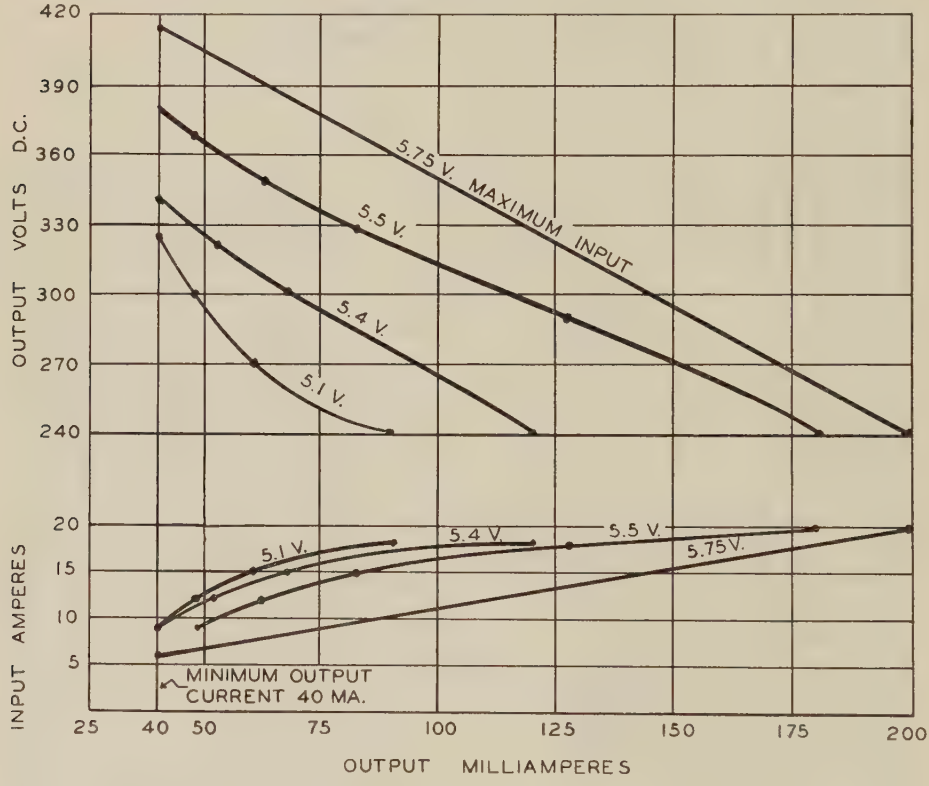

Figure 3.—Operating characteristics of the shocker in 6 inches of water with distances of 6 inches to 4 feet between electrodes.

Operation

The power to operate the shocker is supplied by a 6-volt motorcycle battery. This direct current is changed successively as follows: to low voltage alternating current by a vibrator, to high voltage alternating current by a transformer, and to high voltage direct current by a rectifier. This high voltage direct current is conducted to the electrodes for shocking the fish. The operating characteristics of the shocker

(Fig. 3) were determined in 6 inches of water in a wooden trough, 4 feet long and 14 inches wide, with distances of 6 inches to 4 feet between electrodes. All readings depend on electrode separation and immersion. The drain on the battery ranged from 5.1 to 5.75 volts and from 6 to 20 amperes. The output of the unit ranged from 240 to 415 volts and from 40 to 200 milliamperes. When the battery cannot produce 18 amperes at 5.1 volts, the unit will not start. If the output drops below 40 milliamperes at 240 volts, the unit will cease to operate. If the electrodes should accidentally come closer together than 6 inches at any time, a blown fuse will result, safeguarding the unit from overloading and damage to the component parts.

The shocker has worked quite well in the streams fished so far where depths ranged from 6 inches to 3 feet. Fishing downstream was found to be more effective than fishing upstream. A team of two men is required, one man to operate the shocker and the second man to do the collecting. In clear water with little current, the collector used a dip net and moved along with the operator. In turbid or swift water, the collector used a one-man seine and took up a stationary position while the operator started about 20 feet above and worked down to the seine. Fish were narcotized within 1 foot of the positive electrode. Beyond that, some were attracted to the positive electrode but most appeared to receive a slight shock and moved in all directions. Occasionally fish were led into the seine. All fish recovered quickly.

Since the unit has been quite effective in occasional collections, it shows that a current of 40 to 200 milliamperes is ample for small stream sampling in soft waters. The unit has not been used in hard waters, which would require a higher output current (Haskell *et al.*, 1954). Two fully charged batteries have supplied enough power for a full day's fishing. One battery will operate the unit continuously for 1 hour. Under actual fishing conditions where the unit is not in continuous operation, it is estimated that the battery will operate the unit effectively for a maximum of 2 hours. Fishing time is thus limited by the number of batteries available or distance travelled from a charger. A word of caution is necessary in connection with shutting off the unit. This should be done while the electrodes are immersed in the water so as to drain off any current left in the condensers. Otherwise the resultant shock upon contact with any of the uninsulated parts is quite uncomfortable and may cause other accidents. This danger could be eliminated by inserting a discharge resistor of 400 K across the output leads. It is shown as R-4 in the schematic wiring diagram (Fig. 2).

Acknowledgements

The fish shocker described in this paper was assembled by Mr. A. P. Cowan who is a technician on the staff of the Fisheries Research Board of Canada Biological Station at St. John's, Newfoundland. He also prepared the figures. Mr. W. M. Gaskell, Electrical Equipment Technician with the Newfoundland Light and Power Company, Limited, very kindly checked the technical parts of the paper.

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Experiments with Toxaphene As Fish Poison

by

George E. Stringer and Robert G. McMynn

British Columbia Department of Recreation and Conservation, Fish and Game Branch, 567 Burrard Street, Vancouver, British Columbia.

Introduction

Elimination of undesirable fish species and subsequent re-introduction of preferred species is an effective means of improving sport fishing. Since this form of management is expensive, the volume and number of lakes which can be treated is limited. If a cheaper chemical treatment could be proven, lake rehabilitation through poisoning would become more popular. In this report, the commercial insecticide, Toxaphene (a chlorinated camphene) has shown some promise when tried in a series of alkaline lakes in British Columbia.

Although some information is available concerning the chemistry of Toxaphene and its effects on warm-blooded animals, little critical work has been done on its use as a fish toxicant. Since British Columbia contains many lakes in which the sport fishery would benefit by removal of predator and competitor fish, it seemed desirable to determine the effectiveness and limitations of Toxaphene both with respect to fish as well as to plankton and bottom fauna. To obtain this information, eight small alkaline lakes typical of those found in the interior of the province were chosen. They contained a variety of coarse fish, all were readily accessible, and with one exception, had no permanent inlet or outlet streams.

Methods

In 1954, several British Columbia lakes were treated with "Fish Tox" (a rotenone based chemical containing 10 per cent Toxaphene). These lakes remained toxic for over two years. The prolonged period of toxicity was attributed to the presence of Toxaphene. As a result of this observation, a series of four Toxaphene concentrations was chosen in this experiment ranging downward from 0.10 p.p.m. (concentration represents actual concentration of 100 per cent Toxaphene). The concentrations, 0.01 p.p.m., 0.03 p.p.m., 0.07 p.p.m. and 0.10 p.p.m. were duplicated. Some of the more important physical and chemical features of the experimental lakes are listed in Table I.

Table I

Physical and Chemical Features of Toxaphene Treated Lakes

Name of Lake	Toxaphene Concentration (p.p.m.)	Area (acres)	Mean Depth (feet)	Volume (acre feet)	pH	T.D.S. (p.p.m.)
Alleyne	0.01	135	55	7,425	8.3	308
Taylor	0.01	14	32	463	7.9	249
Gladstone	0.03	22	25	533	7.9	277
Round	0.03	91	58	5,278	8.2	295
Gallagher	0.07	17	34	571	8.2	172
Spectacle	0.07	9	11	96	8.4	285
Summit	0.10	12	30	360	7.9	249
Lady King[1]	0.10	15	18	270	8.2	170

[1] Lady King has an outlet stream discharging about two cubic feet per second.

In addition to the physical and chemical surveys of the lakes, bottom fauna and plankton samples were taken prior to treatment. Poisoning of the lakes took place during the first week of August, 1956. Gill nettings, live cage sets (rainbow trout), plankton hauls, and bottom samplings were carried out after the poisonings at an interval of one month and again at nine months. Periodic checks will continue until the lakes become non-toxic to fish.

Initially, when mixing and handling containers of liquid Toxaphene, workers were completely enclosed in rubber clothing including goggles and respirators. Toxaphene splashed on the skin produced no harmful effects provided that it was immediately washed off with a detergent. Respirators reduced the possibility of inhaling fumes while transferring liquid from one sealed contained to another. When applying the concentrate, only goggles, rubber boots and gloves were found necessary as additional protective clothing. Although all experimental lakes lie within cattle raising country and are used constantly as water holes, no adverse effect on cattle has been noted. Reasonable caution makes the handling and distribution of Toxaphene no more hazardous than other similar chemicals in daily use.

Liquid Toxaphene was easily and quickly distributed by the use of an outboard motorboat, fire pump, a 10 or 20 gallon drum and fittings. The required amount of Toxaphene for each lake was measured into 10 or 20 gallon drums and sealed before being transported to the lake. Each drum was provided with two outlets, one to a shut-off valve and the other to a capped breather pipe. Neoprene connections led from the shut-off valve, first to a needle valve which provided a fine flow adjustment, and then to a domestic water meter. This meter recorded volume delivered but not rate. The latter was calculated from timed runs using water and allowing the pump to operate at capacity. The metered line from the drum was then bled directly into

the suction line of the firepump, which drew water from the lake continuously and at capacity (50 to 75 gallons per minute). Discharge of the mixed dilute Toxaphene was effected by two lines from the pump which released the mixture underwater on either side of the boat.

Toxaphene Effects

Fish

In order to subject as many fish species as possible to the various Toxaphene concentrations, cages containing fish not occurring in the lake were used to augment indigenous species. These were:—

1. Largescale sucker (*Catostomus macrocheilus*)
2. Squawfish (*Ptychocheilus oregonense*)
3. Carp (*Cyprinus carpio*)
4. Redside shiner (*Richardsonius balteatus*)
5. Perch (*Perca flavescens*)
6. Peamouth chub (*Mylocheilus caurinum*)
7. Lake chub (*Couesius plumbeus*)
8. Mountain Whitefish (*Coregonus williamsoni*)
9. Kokanee (*Oncorhynhus nerka*)
10. Rainbow Trout (*Salmo gairdneri*)
11. Prickly sculpin (*Cottus asper*)

At time of treatment, all lakes were thermally stratified with surface temperatures ranging between 64°F. and 67°F. In general fish displayed distress symptoms (erratic swimming, surfacing, and little alarm reaction) within four hours of treatment. Within 48 hours, the majority of fish were dead at all concentrations of Toxaphene; higher concentrations killed more quickly. At 0.10 p.p.m. all caged fish (suckers, squawfish, carp and peamouth chub) had succumbed prior to checking at 48 hours. All caged fish at a Toxaphene concentration of 0.10 p.p.m. died before 96 hours had elapsed. It was noted that a few individuals of a species exhibited remarkable ability to resist the lethal effects of Toxaphene for a prolonged period, while the remainder of the individuals of the same species died more quickly. In Gallagher Lake, one whitefish and one sucker were netted 19 days after the chemical treatment; in Spectacle Lake two caged carp were alive after four days (one was still alive one month later, but died before being checked at six weeks). In Alleyne Lake, one live sucker was netted three weeks after treatment. Gill netting, ($\frac{3}{4}$ inch to $3\frac{1}{2}$ inch mesh) undertaken two to three weeks after treatment showed that all fish had been killed, with the exception of those in the above-mentioned lakes. Simultaneous live cage tests with rainbow trout in Alleyne and Taylor Lakes (0.01 p.p.m.) produced 100 per cent mortalities within a five day period, while controls in adjacent lakes produced almost 100 per cent survivals.

In May, eight to nine months after the poisonings, gill net sets did not produce a single fish in any of the treated lakes. Live cage tests (rainbow trout) produced 100 per cent mortalities within two to seven days, with one exception, in all lakes. Although some of the cages were not checked until the seventh day, it was obvious that the fish had been dead for some time. In Lady King Lake two live cages were utilized; one was set at a depth of five feet and the other at a depth of about 15 feet. After seven days the five foot cage contained no live fish, while the 15-foot cage had a 60 per cent survival after 13 days. This particular lake is the only experimental lake which has a continuous inflow and, since the temperature of the inlet stream (55°F. on June 5) was considerably cooler than that of the lake surface (64°F. on June 5), it is probable that, owing to density difference, the non-toxic inlet waters diluted or replaced the deeper chemically treated waters thereby creating a more favourable enviroment for the survival of fish at that depth. Tables 2 and 3 summarize the results of the Toxaphene treatments on fish.

Table II

Results of Toxaphene Treatments on Fish Within 4 to 120 Hours After Poisoning.

Name of Lake	Fish Present		Initial Results
Alleyne..... (0.01 p.p.m.)	Sucker R. Trout		24-48 hours. Many dead suckers some still in distress
Taylor..... (0.01 p.p.m.)	Sucker [1] Squawfish [1] Carp [1]	Peamouth chub [1] R. Trout Shiner	96 hours. All fish in cages dead.
Gladstone..... (0.03 p.p.m.)	Sucker [1] Squawfish [1] Carp [1]	Peamouth chub [1] R. Trout Shiner	12 hours. Dead shiners and trou many fish in distress.
Round..... (0.03 p.p.m.)	Carp		72 hours. No live fish observed.
Gallagher..... (0.07 p.p.m.)	Sucker Squawfish Shiner Perch	Peamouth chub Lake chub Whitefish Kokanee R. Trout	96 hours. No live fish observed.
Spectacle..... (0.07 p.p.m.)	Sucker [1] Squawfish [1] Carp	Peamouth chub [1] Shiner	120 hours. All caged fish dead. Except 2 carp [2].
Summit..... (0.10 p.p.m.)	Sucker Squawfish Carp	Peamouth chub R. Trout Shiner	4 hours. Many dead trout and shiners. Distress noted in others. 48 hours all caged fish dead.
Lady King..... (0.10 p.p.m.)	Squawfish Shiner Peamouth chub	R. Trout Sculpin	24 hours. No sign of fish life.

[1] Fish held in cages. [2] Dead in 1 to 2 months.

Table III

Results of Toxaphene Treatment on Fish 2 to 3 Weeks and 8 to 9 Months After Poisoning.

Name of Lake	Fish Present		2-3 Weeks After Treatment		8-9 Months After Treatment	
			Gill Net Sets	Live Cage Tests	Gill Net Sets	Live Cage Tests
Alleyne..... (0.01 p.p.m.)	Sucker R. Trout		21 days one sucker[2]	After five days all dead	No fish	Fifty days 100% mort.
Taylor..... (0.01 p.p.m.)	Sucker[1] Squawfish[1] Carp[1]	Peamouth chub[1] R. Trout Shiner	20 days no fish	After five days all dead	No fish	Seven days 100% mort.
Gladstone... (0.03 p.p.m.)	Sucker[1] Squawfish[1] Carp[1]	Peamouth chub[1]	20 days no fish		No fish	Five days 100% mort.
Round..... (0.03 p.p.m.)	Carp		16 days no fish		No fish	Two days 100% mort.
Gallagher.... (0.07 p.p.m.)	Sucker Squawfish Shiner Perch	Peamouth chub Lake chub Whitefish Kokanee R. Trout	19 days, one whitefish,[2] one sucker[2]		No fish	Seven days 100% mort.
Spectacle.... (0.07 p.p.m.)	Sucker[1] Squawfish[1] Carp[1]	Peamouth chub[1] Shiner	19 days no fish		No fish	Seven days 100 % mort.
Summit..... (0.10 p.p.m.)	Sucker[1] Squawfish[1] Carp[1]	Peamouth chub[1] R. Trout Shiner	20 days no fish		No fish	Two days 100% mort.
Lady King... (0.10 p.p.m.)	Squawfish Shiner Peamouth chub	R. Trout Sculpin			No fish	Seven days 100% mort. and 40% mort.

[1] Fish held in cages. [2] Re-netted 74 days after treatment—no fish

Bottom Fauna

An evaluation of the effects of Toxaphene on bottom organisms was attempted. Samples (six inch Ekman dredge) consisting of 30 pre-poisoning and 70 post-poisoning dredgings were taken from each lake. Limitations of this type of sampling preclude quantitative analysis of the data. Qualitative results, however, are summarized in Table 4.

Shrimp (*Gammarus* or *Hyallela*) were taken from six of the eight lakes prior to treatment, but were absent in subsequent dredgings following poisoning. Further observations on the sensitivity of shrimp to Toxaphene were provided by placing shrimp from a nearby lake into cages in Round and Lady King Lakes eight to nine months after poisoning. The cages were set at a depth of about 15 feet and checked after a period of six days. All shrimp in the Round Lake cages were dead; no mor-

talities were noted in the cage in Lady King Lake. The results from Lady King are undoubtedly associated with the inflowing stream and the depth at which the cages were set

Table IV

Occurrence of Bottom Organisms in Toxaphene Treated Lakes Before and After Poisoning.

("x" Indicates Presence of the Particular Form "–" Indicates that the Lake Was Not Sampled, While "o" Indicates that the Organism Was Absent in the Samples).

Organism	Alleyne (0.01)	Taylor (0.01)	Gladstone (0.03)	Round (0.03)	Gallagher (0.07)	Spectacle (0.07)	Summit (0.10)	Lady King (0.10)
	A B C	A B C	A B C	A B C	A B C	A B C	A B C	A B C
Shrimp	– o o	x o o	– o o	x – o	x o o	x o o	x o o	x o o
Midge Larvae	x x x	x x x	x x x	x – x	x x x	x x x	x x o	x x o
Aquatic Earthworms	x x x	x x x	x x x	x – x	x x x	x x x	x x x	x x x
Leeches	o o o	o o o	x x o	o – o	o o o	x o x	x x x	o o x
Mayfly Nymphs	o o o	x x o	x o o	x – o	x o o	x x x	x o o	o o o
Dragonfly and Damselfly Nymphs	x o o	x x x	x x x	x – o	x o o	x x x	x o o	o o o
Freshwater Snails	x x x	x x x	x x x	x – o	x x x	x x x	x x o	x x x

A—Before treatment.
B—One month after treatment.
C—Nine months after treatment.

Midge larvae (*Chironomidae*) were present in all lakes initially as well as one month after application of Toxaphene. Nine months after treatment midge larvae were absent from Lady King and Summit Lakes (0.10) but present in the other lakes. This indicates that at a concentration of 0.10 p.p.m. Toxaphene, midge larvae are either eliminated or greatly reduced in abundance, with death apparently occuring somewhere between one and nine months.

Aquatic earthworms (*Oligochaeta*) were present in all lakes before and after treatment. Leeches (*Hirundinea*) although not taken in all samples were found in the two 0.10 p.p.m. Toxaphene treated lakes nine months after poisoning. It would therefore appear that these forms are unaffected at even the highest concentration of Toxaphene used in the experiments.

Mayfly nymphs (*Ephemeroptera*) were taken in six of the lakes prior to treatment but were absent in subsequent samples from all lakes except Taylor Lake (0.01 p.p.m.). This suggests that mayfly nymphs are killed by Toxaphene concentrations of 0.03 and greater.

Dragonfly and damselfly nymphs (*Odonata*), although taken initially in most lakes, were absent in later samples taken from both the 0.10 p.p.m. and one of the 0.07 p.p.m.

treated lakes. It would seem that a concentration of 0.07 p.p.m. is near the upper limit of tolerance for this group. Lethal effect of 0.10 p.p.m. concentration was amply demonstrated in the case of Summit Lake where numerous dead dragonfly larvae were found one month after application of 0.10 p.p.m. Toxaphene.

Freshwater snails (Gastropoda) were taken in most dredgings and appear to have been unaffected by the dosages of Toxaphene used in the experiments.

Plankton

In order to determine the effect of various Toxaphene concentrations on the more important planktonic groups, qualitative plankton sampling was carried out. The results are summarized in Table 5. Nine months after treatment, rotifers, flagellates and diatoms were present in all samples, with the exception of diatoms in Spectacle Lake (0.07 p.p.m.) (This exception could have been due to sampling error). It is concluded that rotifers, flagellates and diatoms are not adversely affected by the concentrations of Toxaphene used.

Cladocerans were present in all of the lakes following treatment, although one of the two forms was absent in some instances. These results suggest that this group is unaffected by the concentrations of Toxaphene used in the experiment.

It may be seen from Table 5 that occurrence of copepods was erratic. It is suggested that seasonal variation in abundance together with sampling error accounts for these results. In any case, copepods were taken at all concentrations, which indicates that this group is also tolerant of the Toxaphene concentrations used. The available evidence strongly suggests, therefore, that Toxaphene at the concentrations applied in this experiment, has no significant effect on the major planktonic forms.

Table V

Plankton Samples Taken Before and After Toxaphene Treatment.

("x" Indicates Presence of Particular Form, While "o" Indicates its Absence).

Organisms	Alleyne (0.01)	Taylor (0.01)	Gladstone (0.03)	Round (0.03)	Gallagher (0.07)	Spectacle (0.07)	Summit (0.10)	Lady King (0.10)
	A B C	A B C	A B C	A B C	A B C	A B C	A B C	A B C
Cladocera:								
Daphnia	o x x	x x x	x o x	x x o	x x o	x x x	x o o	x x x
Bosmina	x x x	x x x	x x x	x x x	x x x	x o x	x x x	x x x
Copepoda:								
Cyclops	x x x	x x o	x x o	x x x	x x o	x o x	x x o	x x x
Diaptomus	x x o	o o o	o o o	x o o	x x o	x o o	o o o	x o x
Nauplius larvae	x x x	x x o	x x x	o o x	x x x	x o x	x o o	x x x
Rotifera	x x x	x x x	x x x	x x x	x x x	x x x	x x x	x x x
Mastigophora (Flagellates)	x x x	x x x	x x x	x x x	x x x	x x x	x x x	x x x
Bacillariaceae (Diatoms)	x x x	x x x	x x x	x x x	x x x	x x o	x x x	x x x

A—Samples taken before poisoning.
B—Samples taken one month after poisoning.
C—Samples taken nine months after poisoning.

Discussion

Toxaphene is an inexpensive and effective fish toxicant at all concentrations used in the experiment. Since complete kills were obtained even at the lowest concentration, additional treatments will be undertaken using concentrations of 0.005 p.p.m. and 0.0075 p.p.m. Although the lakes were toxic to fish nine months after treatment, it is anticipated that they will be clear within a few months (two of the lakes treated with 0.10 p.p.m. Toxaphene were successfully stocked with fish two years later). Undoubtedly lakes having a continuous outflow would clear much more rapidly.

Prolonged toxicity can be an advantage and disadvantage to the fisheries manager. It may put a lake out of production for a year or more, but it also assures a complete kill, a result which was not always achieved by the use of other fish toxins.

Results of these experiments do not support previous findings (Hemphill, 1954) in which it was stated that waters with a pH of 8.0 or higher treated with a concentration of 0.10 p.p.m. Toxaphene were planted with fish within four weeks. Perhaps the lake referred to had a high flushing rate or the concentration of 0.10 p.p.m. referred to the total amount of commercial product containing a low percentage of Toxaphene.

The British Columbia Research Council was approached concerning the factors which might control the rate of breakdown of Toxaphene in lakes and the possibility of applying chemical neutralizers. Apparently, Toxaphene breakdown is governed by a complexity of factors in which acidity, sunlight, temperature and bacterial action may be involved. It is doubtful that breakdown could be governed by a specific chemical compound.

In general, Toxaphene shows promise as an inexpensive and effective fish toxicant, its value increasing as more information is collected on minimum doses and length of toxicity.

Acknowledgements

The authors gratefully acknowledge the guidance of Dr. C. C. Lindsey in planning the experiment, and the ingenuity of Stuart B. Smith in the design and construction of the distribution equipment. Invaluable assistance was also provided by Departmental personnel especially John Balkwell in applying the chemical.

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1954. Toxaphene as a fish toxin. Prog. Fish. Cult. Vol. 16, No. 1, pp. 41-42.

Abstract

Eight alkaline lakes in British Columbia were treated with Toxaphene at concentrations ranging from 0.10 p.p.m. to 0.01 p.p.m. Effects on fish, bottom fauna and plankton were evaluated. Most of the fish were killed in all concentrations within the first 120 hours. While a few fish were gill-netted, two to three weeks after treatment, none was netted in any of the lakes eight to nine months after poisoning. The lakes were still toxic to fish nine months after treatment as determined by live cage tests. Amphipods (shrimp) were eliminated at all concentrations and were still absent nine months after treatment. Dragonfly and damselfly nymphs were killed at a concentration of 0.03 p.p.m., while midge larvae were killed at concentrations of 0.03 p.p.m. and greater. No consistent adverse effects were noted with respect to plankton. Toxaphene was indicated as being an effective and economical fish toxicant; further work is being carried out with respect to more dilute concentrations and length of toxicity.

Review of Literature

"*Freshwater Fishery Biology*," by Karl F. Lagler, Wm. C. Brown Company, Publishers, Dubuque, Iowa, 1956; 434 pp., 214 figures. Cloth bound. $6.75.

The new enlarged edition contains the same 25 chapters and six appendices as that of 1952 volume, but fortunately several errors and omissions in the previous edition were corrected. However some minor omissions still exist. For instance, on pages 390-402 in *Appendix F*, dealing with the economic classification of freshwater fishes, several are not considered as sport species. In reality the following are taken regularly on hook and line and provide pleasant recreation: smelt, brown bullhead, American eel, sauger and American shad. To this list should be added two species of Pacific salmon (*Oncorhynchus*), coho and chinook (or spring), which are taken on line not only for sport but for commercial purposes as well. In the same *Appendix F*, it is not very clear to us why some anadromous fishes such as sturgeon species (*Acipenser*) are included in the list but others such as tomcod (*Microgadus*), or striped bass (*Roccus saxatilis*) are excluded. Moreover, several species of freshwater fishes are omitted from the list.

In chapters XVIII and XIX, dealing with *Fishery surveys of lakes*, some modern equipment such as echo sounding machines and bathy-thermographs should be mentioned. The section dealing with the *Methods of marking of fish* should be extended to include more recent types of tags, descriptions of which appeared after the publication of the review by Rounsefell and Kask (1946). In the section on *Enumeration of fish eggs* (pp. 106-111), the findings and techniques of more authors, especially recent ones, should be incorporated. A special section on stages of maturity of fish will be equally useful. Also, it would be advantageous for students to have the scientific term added after the common name under each figure of freshwater fishes, mentioned on pages 23-58.

The scientific nomenclature found in *Appendix F* (pp. 388-403) is up-to-date, including all new changes[1] in names of fishes, which were mostly suggested by Dr. R. M. Bailey.

Minor omissions, enumerated above, do not depreciate the real value of this book, already well-known from its earlier editions. Therefore, it is the reviewer's pleasure to recommend to everyone Dr. Lagler's volume, as a very useful and comprehensive treatise on freshwater fishery biology. Numerous illustrations, clear and comprehensive text, selected references at the end of each chapter, good paper all add to the attractiveness of the book. This new revised and enlarged editon is a "must" for every university library and biology teacher's desk—*Vadim D. Vladykov, Department of Fisheries, Quebec.*

[1] The reviewer, however, does not agree with many changes proposed by Dr. Bailey.